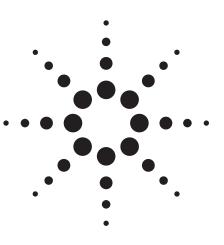
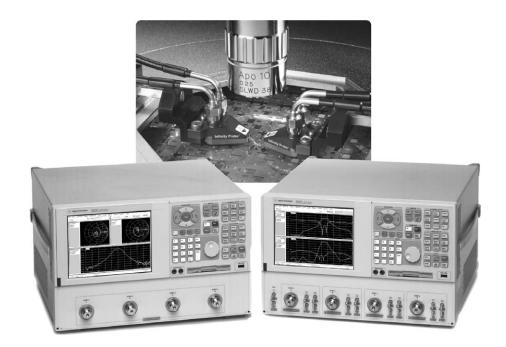
Agilent PNA-L Network Analyzers

Application Note



On-Wafer SOLT Calibration Using 4-port PNA-L Network Analyzers (N5230A Options x4x)





Introduction

This application note is intended for on-wafer applications using the 4-port, PNA-L network analyzers with two dual probes to achieve full 4-port on-wafer calibrations manually. 4-port PNA-L network analyzers are available in 13.5 and 20 GHz models. PNA-L firmware revision must be 6.03 or higher.

This documentation provides step-by-step instructions needed to set up a calibration kit before a 4-port SOLT (Short-Open-Load-Thru) calibration can be performed. The steps outlined here can be applied toward nearly any kind of non-coaxial application, of which on-wafer is one.

Equipment used:

- 4-port PNA-L, N5230A with Option x4x (referred throughout this document as PNA-L)
- Option 140, 300 kHz to 13.5 GHz, 4-port with standard test set
- Option 145, 300 kHz to 13.5 GHz, 4-port with configurable test set
- Option 146, 300 kHz to 13.5 GHz, 4-port with configurable test set and internal second source
- Option 240, 300 kHz to 20 GHz, 4-port with standard test set
- Option 245, 300 kHz to 20 GHz, 4-port with configurable test set
- Option 246, 300 kHz to 20 GHz, 4-port with configurable test set and internal second source
- · Dual probes and associated ISS (Impedance Standard Substrate)



Figure 1. 4-port PNA-L, 13.5 or 20 GHz. Unit on the left shows a standard test set (Option x40), unit on the right shows a configurable test set (Option x45) or a configurable test set with internal second source (Option x46).



Figure 2. Dual line Infinity probe from Cascade Microtech. Available in GSGSG and GSSG configurations with pitches 100, 125, 150, 200, 225, and 250 um. For more details, please contact Cascade Microtech at www.cmicro.com

Implementation

Although a total of six thru paths are present for any 4-port measurement setup, a minimum of only three thru paths are required with the PNA-L to yield a full 4-port SOLT calibration. (If desired, the user can choose to apply all six thru paths; but measuring more paths will take more time and will cause more wear-and-tear of the calibration standards.)

The PNA-L performs 4-port calibrations using either SmartCal (Guided calibration) or an Electronic Calibration (ECal) module. With Guided calibration, the process chooses the standards to apply from the calibration kit based on how they were defined. For on-wafer 4-port calibration, only SmartCal is applicable.

Given that most 4-port on-wafer setups tend to have one dual probe on the left and one on the right, we can assume the ports on the left are 1 and 2, and the ones on the right are 3 and 4, see Figure 3. As can be seen from this illustration, performing on-wafer 4-port calibration using dual probes would require the need to measure thru standards of different lengths because more than one thru configuration must be used during the calibration. Three of the most common configurations are "straight thru," "loop-back thru," and "cross thru," as shown in Figure 4.

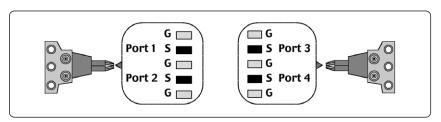


Figure 3. Port assignment used in this application note: ports 1 and 2 on the left, ports 3 and 4 on the right.

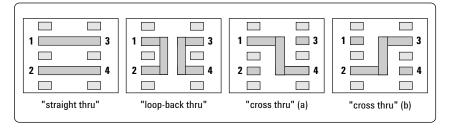


Figure 4. Examples of common thru configurations of a GSGSG probe.

With the PNA-L, the unknown thru calibration method is available and can be applied whenever through standards are not prefect. Since loop-back and cross throughs are in general not perfect, as compared to straight throughs, the unknown thru calibration method provides a much more accurate calibration. This approach is preferred because with the unknown thru method, the through standard does not need to be perfect.

Two major steps are needed to complete a 4-port on-wafer calibration manually using the PNA-L. The details in these steps describe how to properly define a calibration kit and then how to perform the actual calibration.

Step 1. Create a new calibration kit for probing.

Step 2. Perform the SOLT (Short-Open-Load-Thru) calibration.

Step 1. Create a new calibration kit for probing

Note

To create a calibration kit, simply follow the boxed numbers in each of the figures shown below (Figures 5 through 11).

Figure 5:

- 1. Click Calibration
- 2. Select Advanced Modify Cal Kit... this brings up the Edit PNA Cal Kits dialog box
- 3. Click Insert New... this brings up the Edit Kit dialog box

<u>File View Channel Swee</u> p				
Stimulus	Calibration Wizard Preferences	Start	Stop Center Span	
	Correction on/OFF Interpolation ON/off			
	Cal <u>S</u> et CalSet⊻iewer		3	
	Port Extension Tool Bar		J	
	Fixturing on/OFF Eixturing Selections	Edit	PNA Cal Kits	
	ECal Confidence Check C <u>h</u> aracterize ECal Module		Dpen Save As Restore Defaults Installed Kits	
2	Global Delta Match Cal		Import Kit Save As Insert New Print to File	
	Advanced Modify Cal Kit	<u> </u>	ID Kit Name Description	-
	Power Calibration +		25 85039B Type-F (75) Calibration Kit 26 Example Kit A Example Cal Kit with male and female connectors	
	Properties		27 Example Kit B Example Cal Kit with unsexed connectors 28 X11644A X-band Waveguide SOLT/TRL Calibration Kit	
			29 P11644A P-band Waveguide S0L17/TRL Calibration Kit 30 K11644A K-band Waveguide S0L17/TRL Calibration Kit 31 Q11644A Q-band Waveguide S0L17/TRL Calibration Kit 32 H11644A Q-band Waveguide S0L17/TRL Calibration Kit 33 U11644A Q-band Waveguide S0L17/TRL Calibration Kit 34 U144A U-band Waveguide S0L17/TRL Calibration Kit	
			34 WinCal312 WinCal Probe Cal Kit 35 W11644A W-band Waveguide SOLT/TRL Calibration Kit	
			36 OnWafer CMI Cal Kit ◀	Ľ.
		-	Edit Kit Delete	

Figure 5. Creating a new calibration kit for probing.

Figure 6: Connector definition

- 4. Enter Kit Name and Kit Description
- 5. Click **Add** or **Edit** (located near the middle of the dialog box) to add connectors to this calibration kit this brings up the *Add or Edit Connector* dialog box

In order to maximize the benefits of the minimum thru approach (only three thrus, not six, are needed to achieve a full 4-port calibration), it is best to set up a calibration kit with two probes (for example, "probe 1" and "probe 2", or "male" and "female"), and then assign the ports such that it offers the PNA-L the easiest way to execute minimum thru. See Figure 6a for test port assignment. The actual calibration sequence will then be determined by the instrument, via the Calibration Wizard.

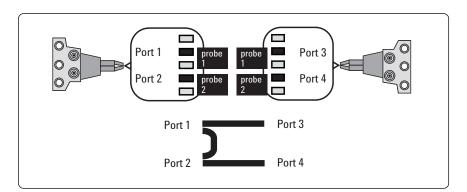


Figure 6a. Assigning test ports as either probe 1 or probe 2 offers the PNA-L the most efficient way of executing minimum thru. This example allows the PNA-L to maximize the number of straight thrus and minimize the number of non-straight ones.

- 6. Enter Connector Family "probe 1" was typed in here
- 7. Select No Gender for connector Gender
- 8. Double check to make sure *Max Frequency Range* is above maximum frequency range of the instrument, for example, 999000 MHz, then click **OK**

Edit Kit Identification Kit Number 37 Kit Name OrtWafer 4P Kit Description Example of OrtWafer 4-Port Cal Kit	4
Family:	I Edit
ID Standard Description	Identification Connector Family probe 1 6 Description probe 1 6 Frequency Range Min 0 MHz Gender Max 99300 8 MHz C Female C No Gender 7
Add Edt Delete All	Z0 50 ohms Media COAX M OK Cancel Apply Help

Figure 6b. Creating a new calibration kit for probing: Connector definition.

Each standard (open, short, load and thru) will be defined with two probes, described here under Connector Family. They are identified as "probe 1" and "probe 2".

As such, repeat steps 5 through 8, this time, enter "probe 2" for Connector Family. At this point, you should have two probes defined under Connectors, and they are "probe 1" and "probe 2"

	Edit Kit 🗵
Add or Edit Connector	Identification
~ Identification	Kit Number 36 Kit Name OnWafer 4P
Connector Family probe 2	Kit Description Example of OnWafer 4-port Cal Kit
Description probe 2	Connectors Class Assignments
Frequency Range Gender	nobe 2 Add or Edit
Min 0 MHz C Male	
Max 999000 8 MHz C No Gender	probe 2 Change Family
Max 999000 8 MHz © No Gender	ID Standard Description
Impedance	To standalu Description
Z0 50 ohms	
- Media	
OK Cancel Apply Help	
	Add Edit Delete Delete All
	OK Cancel Help
l	

Figure 6c. Repeating steps 5 through 8 with probe 2.

Figure 7: Defining OPEN

- 9. Click **Add** (located near the bottom of the dialog box) this brings up the *Add Standard* dialog box
- 10. Select **OPEN**, then click **OK** this brings up the *Opens* dialog box
- 11. Modify Label to read "OPEN 1"
- 12. Under Connector, select "probe 1"
- 13. Enter the CO value, then click OK each ISS (Impedance Standard Substrate) often comes with its own Calibration Coefficients. These values may differ depending on the configuration and pitch of the probes. Typical parameters that come with each ISS include
 - · Copen (the capacitance term for the Open standard)
 - · Lshort (the inductance term for the Short standard)
 - · Lterm (the inductance term for the Load standard)

For more details regarding ISS and its coefficients, please contact Cascade Microtech at **www.cmicro.com**.

Edit Kit	
- Identification	
Kit Number 36 Kit Name On/Wafer 4P	
Kit Description Example of OnWafer 4-port Cal Kit	
Connectors Description: Class Assignments	Opens 🛛
Add or Edt SOLT V Edt	Identification
Family:	Standard ID 1 Label OPEN 1
probe 1 Change Family	Open Description probe 1 open
ID Standard Description	Frequency Range Connector
Add Standard	Min 0 MHz probe1 12
Select the type of standard to be added:	Max 999000 MHz
C DPEN	Open Characteristics
7 с зноят 10	C0 4.7 F(e-15) C2 0 F(e-36)/Hz^2
C LOAD	C1 0 16 F(e-45)/Hz C3 0 F(e-45)/Hz^3
Стнви	Delay Characteristics
C DATA BASED STANDARD	Delay 0 pSec Loss 0 Gohms/s
	Z0 50 ohms
9 Add	
OK Cancel Help	
	Clear OK Cancel Apply Help
	Color Concor Poppy Hop

Figure 7a. Creating a new calibration kit for probing: Defining OPEN.

Repeat steps 9 through 13. This time,

- enter "OPEN 2" for Label (step 11)
- select "probe 2" under Connector (step 12)

Open De:	scription prob	e 2 open	OPEN 2	
Frequency	Range		Connector	
Min 0		MHz	probe 2	12 🖃
Max 9	99000	MHz		
	racteristics	1		
C0 4.	13	F(e-15)	C2 0	F(e-36)/Hz^2
C1 0]JJ	F(e-27)/H	z C3 0	F(e-45)/Hz^3
Delay Cha	racteristics			
Delay 0		pSec	Loss 0	Gohms/s
Z0 5	0	ohms		

Figure 7b. Changing to OPEN 2 and probe 2.

Figure 8: Defining SHORT

14. Click **Add** (located near the bottom of the *Edit Kit* dialog page) - this brings up the *Add Standard* dialog box

- 15. Select SHORT, then click OK this brings up the Shorts dialog box
- 16. Modify Label to read "SHORT 1"
- 17. Under Connector, select "probe 1"
- 18. Enter the LO (Lshort) value, then click OK

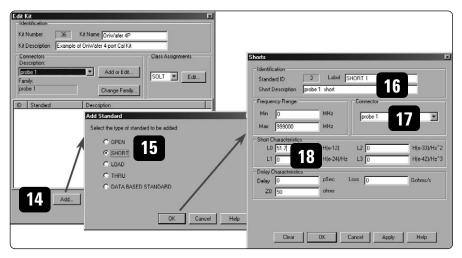


Figure 8a. Creating a new calibration kit for probing: Defining SHORT.

Repeat steps 14 through 18. This time,

- enter "SHORT 2" for Label (step 16)
- select "probe 2" under Connector (step 17)

	Description pro	be 2 short	- Connector	
Min	0	MHz	probe 2	17 🖃
Мах	999000	MHz	probe 2	
Short C	haracteristics			
LO	51.7	H(e-12)	L2 0	H(e-33)/Hz^3
L1	D 18	H(e-24)/Hz	L3 0	H(e-42)/Hz^
Delay (Characteristics			
Delay	0	pSec	Loss 0	Gohms/s
Z0	50	ohms		

Figure 8b. Changing to SHORT 2 and probe 2.

Figure 9: Defining LOAD

- 19. Click **Add** (located near the bottom of the *Edit Kit* dialog page) this brings up the *Add Standard* dialog box
- 20. Select LOAD, then click OK this brings up the Loads dialog box
- 21. Modify Label to read "LOAD 1"
- 22. Under Connector, select "probe 1"
- 23. Enter the following values (because the Loads dialog page does not have an entry for the Lterm):
 - specify a high impedance for **ZO**, enter a value of 500 ohms
 - \bullet enter a value for Delay that is derived from L/500, where L is the value of Lterm as provided with the ISS.

Then click OK.

Edit Kit	
Kit Number 36 Kit Name On/Wafer 4P	
Kit Description Example of OnWafer 4-port Cal Kit	
Connectors Class Assignments	Loads 🛛
Add or Edit SOLT V Edit	Identification Standard ID 5 Label LOAD 1
Family: probe 1 Change Family	Load Description probe 1 load 21
ID Standard Description	Frequency Range Connector
Add Standard	Min 0 MHz probe 1 99
Select the type of standard to be added:	Max 999000 MHz probe 1 22
	Load Type Arbitrary Complex Impedance.
	Fixed Load Impedance Fieal 50
C SHORT	C Sliding Load C Offset Load Imag
C LOAD	Delay Characteristics
C THRU	Delay 0.0262 Delay Sec Loss 0 Gohms/s
C DATA BASED STANDARD	Z0 50 40 hms
19 Add	Offset Load Definition First Offset Standard
He Mad	Second Officer Standard
OK Cancel Help	
	Load Standard OPEN 1
	Clear OK Cancel Apply Help

Figure 9a. Creating a new calibration kit for probing: Defining LOAD.

Repeat steps 19 through 23. This time,

- enter "LOAD 2" for Label (step 21)
- select "probe 2" under Connector (step 22)

oads	
Identification Standard ID 6 Label L Load Description probe 2 load	.0AD 2 21
Frequency Range Min 0 MHz Max 939000 MHz Load Type Arbitrary © Fixed Load © Infreet Load	Connector Probe 2 22 Complex Impedance Real 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Delay Characteristics Delay 0.0262 Z0 50	Loss 0 Gohms/s
Offset Load Definition First Offset Standard Second Offset Standard Load Standard OPEN 2	Y Y Y
Clear OK	Cancel Apply Help

Figure 9b. Changing to LOAD 2 and probe 2

Figure 10: Defining THRU

24. Click **Add** (located near the bottom of the *Edit Kit* dialog page) – this brings up the *Add Standard* dialog box

25. Select THRU, then click OK – this brings up the Thru/Line/Adapter dialog box

The kit, as defined, allows one of the simplest 4-port on-wafer calibrations possible. Although the ISS has several thru lines ("straight thru", "loop-back thru", and "cross thru"), only two thru standards need to be defined. Using the configuration shown in Figure 6a, the two thru standards are best "straight thrus". For this document, one thru will have two "probe 1" as *Connectors* and the other will have two "probe 2" as *Connectors*.

- 26. Modify Label to read "THRU 1"
- 27. Under Connectors, select "probe 1" for both ports

28. Enter the value for Delay as provided with the ISS, then click OK.

Edit Kit	
Kit Number 36 Kit Name OnWafer dP	
Kit Description Example of OnWafer 4-port Cal Kit	
Connectors Class Assignments Description:	Thru/Line/Adapter
Add or Edg	Identification
Family.	Standard ID 7 Label THRU 1 Thru Description Insertable thru standard 26
probe 1 Change Family	Thru Description Insertable thru standard
ID Standard Description	Frequency Range
Add Standard	Min 0 MHz
	Max 999000 MHz
Select the type of standard to be added:	133000 CHIL
C OPEN 25	Delay Characteristics
1 C OPEN C SHORT 25	Delay 2 pSec Loss 0 Gohms/s
C LOAD	Z0 50 28 ohms
C THRU	Connectors
C DATA BASED STANDARD	Port probe 1 Port probe 1
24 Add	
OK Cancel Help	27
	Clear OK Cancel Apply Help

Figure 10a. Creating a new calibration kit for probing: Defining THRU standards.

Repeat steps 24 through 28. This time,

- enter "THRU 2" for Label (step 26)
- select "probe 2" under *Connectors* for both ports (step 27)

hru Description	nsertable thru sta	andard	26	-
requency Range —				
Min 0	MHz			
Max 999000	MHz			
Z0 50 2	ohms			
Port probe 2	•	Port probe 2	:	•
	A		A	
		27		

Figure 10b. Changing to THRU 2 and probe 2.

Figure 11:

29. With the Thru standards added, the calibration kit is now complete. Click **OK**.

30. The calibration kit is now ready for use, as shown here in the Cal Kit list.

Edit Kit	X
Identification	
Kit Number 36 Kit Name OnWafer 4P	
Kit Description Example of OnWater 4-port Cal Kit	
Connectors Class Assignments Description:	
Probe 1 Add or Edt SOLT V Ed	Edit PNA Cal Kits
Family:	UDen Save As Restore Defaults
probe 1 Change Family	Installed Kits
ID Standard Description	
1 OPEN 1 probe 1 open	Import Kit Save As Insert New Print to File
2 OPEN 2 probe 2 open	ID Kit Name Description
3 SHORT 1 probe 1 short	20 85032F TypeN (50) Calibration Kit
3 SHORT 1 probe 1 short 4 SHORT 2 probe 2 short 5 UAD 1 probe 2 short 29	21 85032B/E TypeN (50) Calibration Kit
5 LUAD I probe I load	22 85054B TypeN (50) with sliding load
6 LOAD 2 probe 2 load	23 85054D TypeN (50) Calibration Kit
7 THRU 1 Insertable thru standard	24 850368/E TypeN (75) Calibration Kit
8 THRU 2 Insertable thru standard	25 850398 Type-F (75) Calibration Kit
	26 Example Kit A Example Cal Kit with male and female connectors
	27 Example Kit B Example Cal Kit with unsexed connectors
	28 X11644A X-band Waveguide SOLT/TRL Calibration Kit
	29 P11644A P-band Waveguide SOLT/TRL Calibration Kit
	30 K11644A K-band Waveguide SOLT/TRL Calibration Kit
Add Edit Delete Delete All	31 Q11644A Q-band Waveguide SOLT/TRL Calibration Kit
	32 R11644A R-band Waveguide SOLT/TRL Calibration Kit
OK. Cancel	Help 33 011644A U-band Waveguide SUL1/TRL Calibration Kit
	35 W11644A W-band Wayequide SOLT/TRL Calibration Kit
	36 OnWater 4P Example of OnWater 4-port Cal Kit
	30 Edit Kä Delete
	OK Cancel Help

Figure 11. Creating a new calibration kit for probing: Complete.

Step 2. Perform the SOLT (Short-Open-Load-Thru) calibration

The PNA-L can perform 4-port calibrations with either SmartCal (Guided calibration) or an Electronic Calibration (ECal) module; but is not available with Unguided calibration. Since ECal modules are not applicable for on-wafer, we will use SmartCal, a calibration process in which the steps are guided by the instrument.

For 4-port calibrations, performing SOLT with Unknown Thru yields the best accuracy with the least complexity. Using the port assignment of Figure 6a, the minimum three thru paths to be measured can be the following:

Thru #1	ports 1 – 2	Unknown Thru
Thru #2	ports 1 – 3	Defined Thru
Thru #3	ports 2 – 4	Defined Thru

This way, the two Defined Thru paths measured are each a "straight thru," and we use Unknown Thru to characterize the non-straight thru which in turn can yield better calibrated results.

To perform a full 4-port calibration, simply follow the boxed numbers in each of the figures shown below (Figures 12 through 16).

Figure 12:

- 1. Click Calibration
- Select Calibration Wizard... this brings up the Calibration Wizard: Begin Calibration dialog box
- 3. Select "SmartCal (GUIDED Calibration): Use Mechanical Standards"
- Click Next > this brings up the Select Guided Calibration Type (Mechanical Standards) dialog box
- 5. Under Cal Type Selection, make sure "4 Port Cal" is selected
- Click Next > this brings up the Guided Calibration: Select DUT Connectors and Cal Kits dialog box

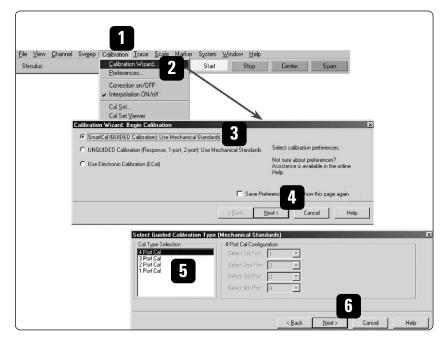


Figure 12. Begin calibration.

Figure 13:

- 7. Under *Connectors*, using the dropdown menu, select **"probe 1"** for ports 1 and 3, and select **"probe 2"** for ports 2 and 4 (as shown in Figure 6a).
- 8. This is the view one can expect after repeating step 7 for all four DUT Ports.
- 9. Once the connector has been chosen (steps 7 & 8), the associated Cal Kits will

appear. Since there is only one calibration kit defined with *Connectors* of **Probe 1 and Probe 2**, **OnWafer 4P** will automatically appear under *Cal Kits*. If you have more than one calibration kit defined with the same connector, then you would need to select the desired cal kit for this calibration via the dropdown menu.

- 10. Select **"Modify Cal"** by clicking on the box. You must select this in order to be able to choose the Thru standard of your choice for each path.
- 11. Click **Next >** this brings up the *Modify Cal* dialog box
- 12. A minimum of three thru paths are needed to achieve a full 4-port SOLT calibration. This example shows the thru paths of 1-2, 1-3, and 2-4 (column on the left); and they were chosen primarily for convenience. (A total of all six thru paths can also be selected, but it is not necessary for the full 4-port SOLT calibration. Additional thru paths can be enabled on the right side.)
- 13. Under *Thru Cal Method*, one must use the dropdown menu to select the method of choice. Available choices include "Defined Thru," "Unknown Thru," and "Adapter Removal." Default shows Defined Thru. Choose **Defined Thru** for the "straight thru" paths; these include paths 1-3 and 2-4. For the "loop-back thru," choose **Unknown Thru**; this includes path 1-2.
 - "Defined Thru" applicable when used with a pre-defined adapter because the calibration process will apply the adapter information supplied in the definition. Delay value of the adapter must be reasonably close to the actual value (±90 degrees, ± 1/₄ λ); otherwise, phase could be 180 degrees out.
 - "Unknown Thru" ideal for non-straight or non-insertable thru, this must be
 a passive device where its forward and reverse characteristics are the same;
 as such, it is also referred to as "reciprocal thru." The calibration process will
 measure the unknown passive device, determine its delay value, and then apply
 it in order to complete the calibration.
 - "Adapter Removal" applicable when used with an unknown adapter because the calibration process will attempt to characterize the adapter before its effects are removed.
- 14. Click Next >

Guided Calibration: Select	DUT Connectors and C	al Kits		×	
Conn	ectors	Cal Kits			
DUT Port 1 APC 3.5 mak	e 💌 850528	-	Cal Method: 4-Port		
DUT Port 2 1.85 mm fem					
DUT Port 3 1.85 mm mak	e 				
DUIT Port 4 1.00 mm fem					
Modify Cal 7-16 male	1000004				
APC 7	a Cal Mathed	nd/or standards used for the selected	d cal hite		
Type N (50) r Type N (50) r	male	indion standards used for the selected	J Call Kits.		
Type N (75) r	male	< Back Next>	Cancel	Help [
Type N (75) f Type F (75) n		(Dack How)		riap	
Type F (75) fr Type A (50) r	emale				
Type A (50) f	female Gui	ded Calibration: Select DUT Co			×
Type B X-band wave	anida.	Connectors		Cal Kits	Cal Method: 4-Port
P-band wave	aguide	DUT Port 1 probe 1	▼ OnWater 4P		
K-band wave		DUT Port 2 probe 2	OnWafer 4P		
R-band wave	eguide	probe 1	OnWafer 4P	<u> </u>	
U-band wave V-band wave	equide	DUT Port 4 probe 2	OnWafer 4P		
W-band way probe 1	Conception of the local division of the loca	Modify Cal			
probe 2	OF	TIONAL. Select [Modify Cal] to chan	ge the Cal Method and&	or standards used fo	oal kits.
WRD180 WRD750		4.0			
WRD650	v	10		< <u>B</u> ack <u>N</u> ext >	Cancel Help
	_				
	Mod	lify Cal			×
	_T	hru Calibration Options (Cal Type: 4-			
		Thru Cal M			
		Thru #1 1-2 💌 Unknown Thr	Mod Stds	Thru #4	
		Thru #2 1-3 Thefined Th	Mod Stds	🗂 Thru #5	
		Thru #3 24 Thefined Th	Mod Stds	, 🗖 Thru #6	
			7		
		7		Choose delta match	
		12	-	< <u>B</u> ack <u>N</u> ext>	Cancel Help

Figure 13. Select Connectors, Cal Kits, and Thru paths.

At this point, you should see the dialog box showing "Guided Calibration Step 1 of 15," which is the beginning of the calibration.

Using Guided Calibration, the network analyzer will step the user through 15 steps (as shown in part (a) of Table 1), allowing the user to calibrate one port at a time. For each test port, the instrument steps the user through three standards (Open, Short, and Load) before advancing to the next test port. This approach is optimized for coaxial calibration, but not for probing. To be efficient in probing, a better approach would be to minimize the number of touchdowns, while maximizing the number of measurements possible for each touchdown. Such a scenario would only require seven touchdowns instead of 13 in order to complete a full 4-port SOLT calibration. To measure the standards in a different order than suggested by the Guided Calibration process, click the **Next** > softkey to skip standards (for example, to measure all the Opens at one time, as shown in part (b) of Table 1), and then click the **Shorts** and the Loads). Continue to move back and forth until all the necessary steps have been measured.

Table 1. Steps as Guided by the PNA-L (a) and sequence to be measured to minimize the number of probe touchdowns (b).

(a) Steps as guided	by the PNA-L:		
Step 1 of 15	Port 1 OPEN 1		
Step 2 of 15	Port 1 SHORT 1		
Step 3 of 15	Port 1 LOAD 1		
Step 4 of 15	Port 2 OPEN 2		
Step 5 of 15	Port 2 SHORT 2		
Step 6 of 15	Port 2 LOAD 2		
Step 7 of 15	Port 1 ADAPTER Port 2 \leftarrow this is the Unknown Thru		
Step 8 of 15	Port 3 OPEN 1		
Step 9 of 15	Port 3 SHORT 1		
Step 10 of 15	Port 3 LOAD 1		
Step 11 of 15	Port 1 THRU 1 Port 3		
Step 12 of 15	Port 4 OPEN 2		
Step 13 of 15	Port 4 SHORT 2		
Step 14 of 15	Port 4 LOAD 2		
Step 15 of 15	Port 2 THRU 2 Port 4		
., .	equence to be measured to minimize the number of touchdowns:		
Port 1 OPEN			
Port 2 OPEN 2			
Port 3 OPEN 1			
Port 4 OPEN 2			
Port 4 SHORT 2			
Port 3 SHOR	T1		

Port 1 | ADAPTER | Port 2 ← this is the Unknown Thru

Port 2 | SHORT 2 Port 1 | SHORT 1 Port 1 | LOAD 1 Port 2 | LOAD 2 Port 3 | LOAD 1 Port 4 | LOAD 2 Port 2 | THRU 2 | Port 4 Port 1 | THRU 1 | Port 3 Throughout the calibration process, one sees the "Guided Calibration Step" shown on the upper left corner of the dialog box (Figure 14), the Measure button is on the right, and the < Back and Next > buttons are toward the bottom. Once a standard has been measured, a green "check" symbol appears above the ReMeasure button which is located at the exact spot where the Measure button used to be. After all the standards have been measured, a green Done button will appear below the ReMeasure button. You can always go back to re-measure any standard before pressing the Done key. At this point, one can finish the calibration by simply clicking Done, or choose to re-measure another standard as needed.

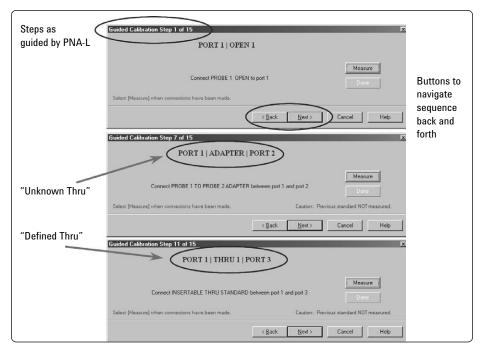


Figure 14. Samples of screens throughout the calibration process.

Once **Done** has been selected, the calibration is finished and it is then turned on with **C 4-P** appearing on the status bar (located at the bottom of the display) to indicate that the 4-port error-correction is now active.

Conclusion

The 4-port PNA-L (N5230A Opt.x4x) network analyzer can be used for manual calibration of on-wafer, or any non-coaxial applications. In fact, the steps outlined here can be used for any calibration process where the user needs to create their own calibration kit and follow their own sequence in order to minimize the number of connections or touchdowns (in the case of wafer probing).

Web Resources

For additional product information and application literature, visit our Web sites:

PNA Network Analyzers: www.agilent.com/find/pna

Electronic Calibration (ECal) modules: www.agilent.com/find/ecal

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